Acquisition of number agreement
Effects of processing demands

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Abstract: This study aimed to assess the extent to which the acquisition of number agreement in written French is influenced by the cognitive cost of processing demands associated with (a) the handwriting activity itself, (b) the lexical spelling complexity of the words and (c) the complexity of the sentences to be written. Children from grades 5 and 6 were asked to write dictated sentences in various conditions: they were either asked to write whole sentences, or to write only a word (noun, adjective or verb) within a sentence, or to only complete the endings of words within a sentence. Results showed that children are sensitive to these three factors: (1) children correctly marked more agreements when they were required to complete the endings of words than when they were required to write whole words; (2) children correctly marked more agreements for simple nouns, adjectives and verbs than for complex ones; (3) children were more successful at agreeing the verb when the sentence structure was simple than when it was complex. More precisely, low-level spelling children were more sensitive to these three factors than high-level spelling children. The study shows that the way children made nouns, verbs or adjectives agreements depends on the cost of simultaneous processing demands such as the handwriting activity, the lexical spelling complexity of the words or the sentence complexity.

Keywords: number agreement, spelling acquisition, handwriting cost, lexical complexity, sentence structure

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1. Introduction

The acquisition of grammatical spelling has been the subject of many studies, with a view to either establishing the chronology for the gradual mastery of number agreement (e.g., Beers & Beers, 1992; Largy, 2001; Nunes, Bryant, & Bindman, 1997a; Nunes, Bryant, & Bindman, 1997b; Totereau, Thevenin, & Fayol, 1997), or describing the development of the cognitive processes involved in the production or revision of this agreement (notably Fayol, Hupet, & Largy, 1999; Frisson & Sandra, 2002; Kemp & Bryant, 2003). In order to produce agreements, children have to progressively develop an automated procedure, similar to those used by adults (Fayol *et al*., 1999). During the acquisition period (from around 7 to 11 years), grammatical agreement seems to be a rather complex and resources-consuming operation. Initially, children are able to interpret the marks [e.g., to choose the good picture – with one or two fishes – matched with the label "*les poissons*" (fishes)] and to detect errors [e.g., "*la bague brillent*" (the ring sparkle")] even though they do not normally produce agreement marks (Largy, 2001; Totereau, 1997). They then gradually learn to apply their declarative knowledge (e.g., "when the noun is plural, I need to add an "-s"; Anderson, 1982, 1995). Finally, this sequence of actions gradually becomes automatic; the agreement marks are produced automatically without voluntary recall of the rule (Fayol *et al.*, 1999). But why is the agreement process so difficult to set up?

When children are learning grammatical agreement rules (i.e., at around 7 to 8 years of age), they have to perform several processes in parallel if asked to write from dictation. Firstly, writing itself implies relatively fine control of motor activity and attentional focus, especially as this activity is far from being automatic at this age (Zesiger, 1995). This graphic activity, which we shall refer to as the "handwriting activity", at least at the beginning, requires an unusual amount of cognitive resources. In several studies, Bourdin and Fayol (1994, 1996, 2000) showed that writing is cognitively costly, especially when children start to learn how to write, (i.e., when handwriting does not come automatically). They showed for example that children from second and fourth grades recalled fewer words in a written recall condition than in an oral one. Other studies (for a review, see Peverly, 2006) showed that writing speed influences both the quality and quantity of the written work produced by children or adults. A writing task clearly involves a certain cognitive cost and requires cognitive resources that are thus no longer available for other types of processing.

In addition, the lexical spelling complexity of the words represents a particular difficulty to be overcome by children during the production of written language. Many languages present a particular challenge due to their inconsistency or lack of transparency; in French – but it is also the case in English – about 50% of the words encountered are not written as they are pronounced, due to the inconsistencies of many sound-to-spelling transcription rules (Véronis, 1988). Mastering such inconsistencies involves processes – which we shall refer to as "lexical spelling processing" – that are also likely to consume resources. Alegria and Mousty (1996), Leybaert and Alegria

(1995) and Weekes *et al*. (2006) observed that consistency affects spelling acquisition: children clearly find it easier to spell words containing consistent phoneme-grapheme conversions [e.g., /s/ ➔ written "s": "*sel*" ("salt")] than words containing inconsistent phoneme-grapheme conversions [e.g., /s/ ➔ written "c": "*cigare*" ("cigar")].

Finally, the type of syntactic structure is also likely to have particular influence on the number agreement of the verb. In a task involving the oral completion of sentences, Bock and Cutting (1992) observed that the participants made more agreement errors in sentences in which the subject and the verb were separated by a long phrase containing a second noun that could be a plausible subject for the verb, while they made fewer agreement errors in sentences in which the subject was immediately followed by the verb. Sandra, Frisson and Daems (1999) with Dutch adults and Frisson and Sandra (2002) with Dutch children argued that the accessibility of syntactic information is relevant: when the distance between the subject and the verb is short, the syntactic information is more accessible [e.g., " *Ik treed in mijn vaders voetsporen" vs. "… omdat ik in het strenge klooster treed"* ("I follow in my father's footsteps" *vs*. "…because I enter the strict monastic order")]. The cognitive cost associated with agreement would thus vary according to the type of syntactic structure of the sentence.

In short, handwriting, lexical and structural processing can be more or less demanding in terms of cognitive resources. If one considers that novices have few cognitive resources left (because some are already used to segment words, to map phoneme-grapheme, etc.), it can be hypothesised that cognitively demanding handwriting, lexical and structural processing will consume the greatest part of the available resources and thus affect the way agreement is handled. The present study aims to assess the extent to which these three factors (handwriting activity, lexical spelling complexity, syntactic structure) intervene in the acquisition of number agreement. As mentioned in the introduction, the cognitive cost of each of these factors has been separately established in previous studies, but up to now no study has examined their joint influence (each of these factors having been assessed in different tasks) and no study has so far examined how their joint influence might affect the acquisition of number agreement.

In this study, in order first to assess the effects of handwriting costs on the production of agreements, sentences were presented orally and simultaneously in an incomplete written format; the children were either asked to write whole words or only to complete the endings of words. In both cases, words to agree (nouns, adjectives, verbs) were either simple or complex in order to assess the effects of the lexical spelling processing costs. In another task, the same children were asked to write sentences varying in structural complexity, in order to assess the effects of the cognitive cost of structural processing.

It was hypothesised that children would make more agreement errors under conditions in which they are assumed to be overloaded. For example, children should make fewer correct agreements in the "writing" condition than in the "completing" condition, and fewer in the complex words condition than in the simple words

condition. It was further hypothesised that this effect would vary depending on the children's spelling level.

2. Method

2.1 Participants

Forty-seven primary school children from grade 5 (mean age: 10 years 8 month; ranging from 9 years 9 month to 12 years 1 month) and grade 6 (mean age: 11 years 6 month; ranging from 9 years 9 month to 12 years 7 month) participated in this study. In order to ascertain that they had normal abilities in written language, all the participants were assessed by a reading comprehension test and a spelling test. The reading comprehension test (Lobrot, 1967) assesses children's ability to process sentences at a morphosyntactic level. It consisted of a multiple-choice test involving the completion of 36 sentences; a word was missing from each sentence and the children had to select the missing word from five possible options. The options included distractors such as homophones [e.g., "*mère*" (mother) instead of "*mer*" (sea)], while others included phonological distractors [e.g., "*palais*" (palace) instead of "*balai*" (broom)] or semantic distractors ["*pattes*" (legs) instead of "*oreilles*" (ears)]. The children had 5 minutes to complete as many sentences as possible. The spelling test (Chevrie-Muller, Simon, & Fournier, 1997) involves dictation of a text entitled *"Le Corbeau"*; performance is rated on a phonological level (phoneme-grapheme conversions), on a spelling level (lexical spelling of the words) and on a grammatical level (grammatical rules). Twelve children were eliminated from the initial sample, either because they had obtained a score of less than -2 standard deviations for their age in the spelling or reading test, or because they were or had been receiving speech therapy for difficulties with the written language, or because they were to be considered as bilinguals on the basis of the following criterion: speaking another language for more than 7 hours a week (criterion adopted by Marchman, Wulfeck, & Ellis Weismer, 1999).

Our final sample was thus composed of 35 children aging from 9 years 9 month to 12 years 1 month. Since our study relates to spelling ability (grammatical), children were bracketed in two groups according to their performance in the spelling test: 15 low-level spelling children – who achieved a score between 48 and 57 in the "*Corbeau*" (max score = 70); 20 high-level spelling children – who achieved a score between 58 and 70 in the "*Corbeau*". Table 1 provides the characteristics of the two groups.

2.2 Materials

Two tasks were administered in this study: in the first one, children were asked to write nouns, adjectives and verbs so as to complete dictated sentences; in the second one, they were asked to write whole sentences under dictation.

Table 1. Characteristics of children by spelling level

Level	N	Spelling scores	Reading scores	Age (years; months)
Low	15	52.0 (48 - 57)	31.5 (28 - 36)	11;0 (10;2 - 12;1)
High	20	62.3 (58 - 68)	33.1 (26 - 36)	11;3 (9;9 - 11;11)

2.2.1 Task 1: words

The first task includes 72 lexical items to be written within sentences that were dictated by the experimenter (24 nouns, 24 adjectives and 24verbs). All the words are in common usage: they all occur with a frequency above 48, which corresponds to the 75th percentile of the frequency distribution for grades 3 to 5 according to Manulex (Lété, Sprenger-Charolles, & Colé, 2004).

Children were orally presented with sentences that were simultaneously presented in an incomplete written format; in order to observe the effects of the cognitive cost of *lexical spelling processing*, the lexical spelling complexity of the words to be written was varied by manipulating the consistency, length and syllable structure of these words. In the simple cases, the words were consistent (consistent phoneme-grapheme conversions), short (3-5 letters) and had a simple syllable structure (CVCV) [e.g., nouns *"les jupes"* (the skirts), adjectives *"des chats malins"* (crafty cats), verbs *"les papas fument"* (the fathers smoke)]. In the complex cases, the words were inconsistent (average: 2 inconsistencies), long (10-12 letters) and had a complex syllable structure (CVCCVCVC) [e.g., nouns *"les personnages"* (characters), adjectives *"des chats domestiques"* (domestic cats), verbs *"les papas plaisantent"* (the fathers tell jokes)].

In the same task, in order to observe the effects of *handwriting activity*, the children were either asked to write whole words under dictation [e.g., *"les motos"*] or only to complete the endings of words under dictation [e.g., *"les militaires étal__(-ent)…"*(the soldiers spread__…)]. In the completing task, the children had to write one, two or three letters of a word; so as to prevent the children from focusing on the agreement mark wherever possible the break was not made at the grammatical inflection point (as by Fayol, Totereau, & Barrouillet, 2006 for example); instead, it was made between the penultimate letter and the last letter of the word so that the children had to add at least one letter, even in the case of singular words [e.g., "*la poul_*" (the hen)].

In order to neutralise the effects of other factors outside the writing task, two parallel lists of items were created. List A was used for the writing condition and list B for the completing condition. The equivalence of the two lists was checked with regard to the following variables: word length, word consistency, frequency (Manulex) and level of acquisition of lexical spelling (EOLE, Pothier & Pothier, 2003). The equivalence of the two lists was tested on twenty children from grade 5 who met the same selection criteria as for the study as a whole. These children received words from the two lists

mixed together, in a writing condition. The analysis of their performance showed that the list effect is not significant ($F(1, 19) < 1$; mean percentage of correct agreements for list A = 72.8, mean list B = 72.7), which confirms that the two lists had similar levels of difficulty. Table 2 shows the mean values and standard deviations for the variables manipulated in this study. Appendix A shows the experimental items.

Table 2. Mean values and standard deviations for the variables manipulated in the items: word section

Types of items	Number of letters [a]	Number of inconsistencies [b]	Number of clusters (CCV) [c]
Simple nouns - list A	4.1 (0.8)	0	0
Simple nouns - list B	4.0 (0.5)	0	0
Complex nouns - list A	10.4 (0.7)	2.1 (0.9)	1 (0.0)
Complex nouns - list B	10.4 (0.7)	2.2 (0.7)	1.1 (0.3)
Simple verbs - list A	4.5 (0.5)	0	0
Simple verbs - list B	4.2 (0.7)	0	0
Complex verbs - list A	9.4 (0.7)	1.7 (0.7)	1.2 (0.7)
Complex verbs - list B	9.4 (0.5)	1.8 (0.9)	1.2 (0.7)
Simple adjectives - list A	4.2 (0.7)	0	0
Simple adjectives - list B	4.7 (0.5)	0	0
Complex adjectives - list A	10.7 (0.5)	2.3 (1.2)	1.1 (0.3)
Complex adjectives - list B	11.1 (0.8)	2.1 (1.4)	1 (0.0)

Note. [a,b,c] The three variables are significantly different between simple and complex items (number of letters: $t(53) = -40{,}32$; $p < .001$; number of inconsistencies: $t(53) = -14{,}84$; $p < .001$; number of clusters : $t(53) = -18{,}19$; $p < .001$).

2.2.2 Task 2: sentences

The materials used in the second task consist of 12 sentences to be written under dictation. Two types of sentence structures were presented to the participants to observe the effects of the cognitive cost of structural processing: sentences with a short or a long syntactic distance between the subject and the verb; either sentences in which the verb immediately follows the subject (example 2a) or sentences in which a complement of the subject is inserted between the subject and the verb (example 2b). Sentences of this latter type include a complex noun-phrase of the type N1 of N2 in which it is N1 that governs the verb agreement.

2a. Les touristes observent les animaux de notre région (The tourists watch the animals in our region)
2b. Les filles de ce célèbre musicien chantent ce soir (The daughters of this famous musician sing this evening)

To ensure that the sentences were equivalent in both cases, the following variables were checked: the length of the sentences in terms of the number of letters (between 42 and 48 letters) and the level of acquisition of lexical spelling for the words used in the sentences (EOLE). The mean success rate percentages for the words making up these sentences were similar in both cases, as was the total number of words outside the level, i.e., the words that were not spelled correctly by 75% of the children in this age group. Both tasks were pre-tested to ensure that they had been designed correctly. Table 3 provides characteristics of the variables manipulated. Appendix B shows the list of sentences.

Table 3. Mean values for the variables manipulated in the items : sentence section

Type of sentences	Total number of letters	Number of letters [e] S-V [a]	Level of acquisition of words [b]	Number of words outside level of acquisition [c]
Simple	45.2	0.0	87.8	7
Complex	45.0	18.6	87.8	7

Note. [a] number of letters between the subject and the verb ; [b] percentage of level of acquisition of lexical spelling for CM1 as per EOLE ; [c] number of words outside level of acquisition of lexical spelling as per EOLE (< 75 %)

2.3 Procedure

The children were tested in groups within their classroom over two or three sessions each lasting 45 minutes. To ensure that the children understood the instructions (writing whole words and completing), an example was given, followed by a practice item with corrective feedback given on an individual basis. In the first task, the children had to listen to the sentence, then write the missing words or complete the words in bold by adding one, two or three letters. In the second task, the children had to listen to the sentence, and then to transcribe it entirely. Appendix C shows the instructions given to the children. The tests were taken in an identical order across the different classes. The whole word writing task was performed before the completing task to minimise interference between the tasks. This is because the completing task could be viewed as drawing the child's attention to agreement. To create the order of items, a semi-random order was used with the following criteria: (1) two items of the same type could not

follow each other (e.g., two simple noun items); (2) in the case of adjective and verb items that have the same noun [e.g., *"les livres rares" vs. "les livres exceptionnels"* (the rare books *vs.* the exceptional books)], there should be at least four items between two adjectives or verbs with the same noun; (3) the order in which simple and complex items appear should be alternated: in half of the items, the simple adjective or verb must appear first and in the other half, the complex adjective or verb must appear first. In order to prevent the children from realizing the purpose of the task, items with a singular agreement were incorporated into each task. The first task of the study thus included 72 items to agree in the plural and 36 items to agree in the singular. In the second task, six sentences with a singular verb agreement were incorporated [e.g., *"La sœur de notre meilleure amie gagne souvent au tennis"* (Our best friend's sister often wins at tennis)]. Again, a distracting missing word was inserted in each sentence with the aim of concealing the purpose of the task. These words were either determiners, prepositions or adverbs. For example, for the target item "*hélicoptères*" (helicopters), the sentence was "*Dans ___ (le) ciel, les _____(hélicoptères) arrivent par deux"* (The _____ (helicopters) arrive in __ (the) sky in pairs), where "*le*" (the) is the distracting missing word. The position of the target item in the sentence was varied: either in the initial position [e.g., *"Le dentifrice était tombé par terre"* (the toothpaste had fallen on the floor)], or in the mid-position *[e.g., "Nous avons pris les vélos pour aller à la mer"* (We took the bikes to go to the sea)], or in the final position [*e.g., "Devant leur porte, ils avaient mis des citrouilles"* (Outside their door they had put pumpkins)]. Sentence length was monitored across the writing and completing tasks.

3. Results

In the first task involving writing nouns, adjectives and verbs under dictation, the dependent variable was the percentage of words with correct agreements, whether singular or plural and irrespective of whether the word was spelled correctly or not (in lexical terms) [e.g., "*partissipe*" (partissipates -spelled incorrectly-), "*giguanteste*" (giguantik -spelled incorrectly-)]. Table 4 shows the percentages of correct answers per spelling level as a function of the handwriting condition, lexical spelling complexity of the words and word class. On the whole, children correctly agreed 82 % of the items; mistakes consisted either in omitting the plural marker [15 %, e.g., "*les fleur*"], or in using a wrong marker [3 %, e.g., noun mark "*s*" instead of verb mark *"ils mange<u>s</u>"*]. No transcription error was observed (0 %, e.g., spell another word than the one dictated). An analysis of variance was performed with three intra-subject factors: handwriting condition (full writing, completing), lexical spelling complexity of the words (simple, complex), word class (nouns, verbs, adjectives) and one inter-subject factor: spelling level of the participants (low-level, high-level).

The *spelling level* was significant [$F(1, 33) = 22.32$; $p < .001$]. Low-level children made fewer correct agreements (71.2%) than high-level children (91.0%). The *handwriting condition* was significant [$F(1, 33) = 15.49$; $p < .001$]: children correctly

marked more agreements when they were simply required to complete the endings of words (83.7%) than when they were required to write whole words (78.5%). As shown in Figure 1, the interaction between handwriting condition and spelling level was significant [$F(1, 33) = 4.49$; $p < .05$]; while low-level spelling children were influenced by the handwriting activity [$F(1, 14) = 16.34$; $p < .01$], high-level spelling children were not [$F(1, 19) = 1.89$; $p = .18$]. The *lexical spelling complexity of the words* was significant [$F(1, 33) = 21.67$; $p < .001$]. The children correctly marked more simple nouns, adjectives and verbs (83.1%) than complex ones (79.1%). As shown in Figure 2, the interaction between spelling level and lexical spelling complexity of the words was significant [$F(1, 33) = 9.71$; $p < .01$]; low-level spelling children were sensitive to the complexity of words [$F(1, 14) = 24.33$; $p < .001$] whereas high-level spelling children were not [$F(1, 19) = 1.47$; $p = .24$]. As shown in Figure 3, the interaction between lexical spelling complexity of the words and handwriting activity was also significant [$F(1, 33) = 30.26$; $p < .001$].

Table 4. Mean performance scores in percentages (standard deviations between brackets) as function of spelling level, word class, lexical spelling complexity of the words and handwriting condition.

	Nouns		**Adjectives**		**Verbs**			
Level[a]	**Simple**	**Complex**	**Simple**	**Complex**	**Simple**	**Complex**	**Simple**	**Complex**
				Writing task				
Low	82.9 (20.1)	68.9 (17.9)	62.2 (22.9)	48.9 (14.4)	75.6 (21.4)	64.4 (22.3)	73.6 (18.5)	60.7 (15.1)
High	95.6 (9.1)	90.0 (12.4)	87.8 (16.1)	81.7 (19.8)	95.6 (7.6)	88.3 (12.7)	92.9 (8.8)	86.7 (11.7)
				Completing task				
Low	83.7 (16.1)	83.7 (19.6)	68.9 (20.6)	67.4 (23.9)	73.3 (23.6)	74.1 (22.5)	75.3 (18.8)	75.1 (19.3)
High	96.7 (6.3)	98.3 (4.1)	81.7 (12.6)	93.3 (9.8)	92.8 (14.5)	90.6 (14.1)	90.4 (7.2)	94.1 (6.2)

Note. [a] Low level: n = 15; high level: n = 20

Complexity had a significant effect in the writing condition [$t(34) = 5.95$; $p < .001$], but not in the completing condition [$t(34) = 1.68$; $p = .10$]. When required to write whole words, children made more correct agreements for simple words (84.7%) than for complex ones (75.5%). The *word class* effect was significant [$F(2, 66) = 33.87$; $p < .001$]. A Bonferroni test shows that nouns (87.5%) were significantly better agreed than verbs (81.8%) which in turn were better agreed than adjectives (74.0%). This difference between word class was observed for high and for low-level spelling children. However, this difference was more sizeable for children in the low spelling level [$F(2, 28) = 22.92$; $p < .001$] than for children in the high spelling level [$F(2, 38) = 9.99$; $p <$

.01]. This is the reason why the interaction between word class and spelling level was significant [$F(2, 66) = 3.68$; $p = .03$] (see Figure 4). The other two-way or three-way interactions were not significant.

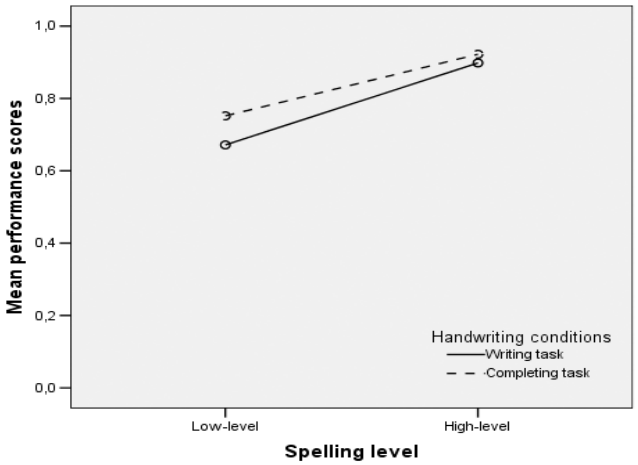

Figure 1. Mean proportions of correct agreements as a function of spelling level and handwriting conditions

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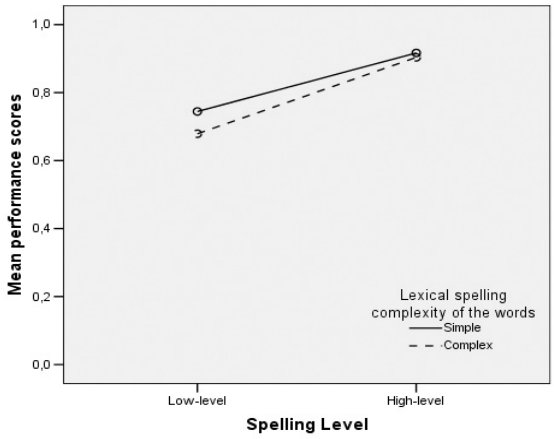

Figure 2. Mean proportions of correct agreements as a function of spelling level and lexical spelling complexity of the words

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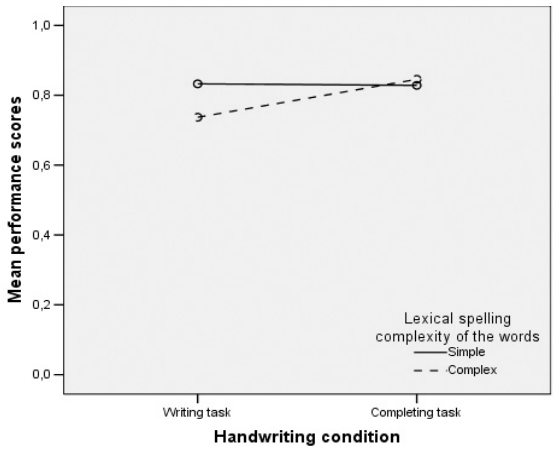

Figure 3. Mean proportions of correct agreements as a function of handwriting condition and lexical spelling complexity of the words

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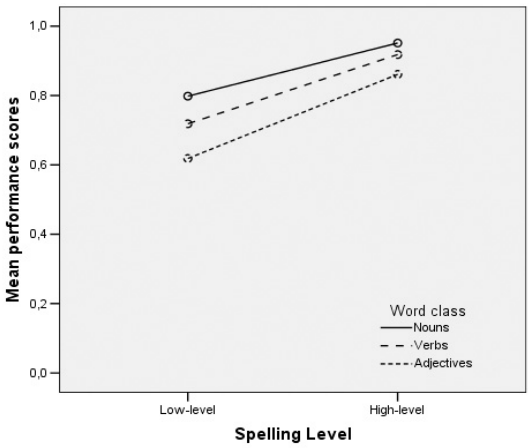

Figure 4. Mean proportions of correct agreements as a function of spelling level and word class

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The conclusions of this analysis of variance are further supported by the results of an analysis of covariance using the spelling level as a co-variable instead of an inter-subject factor. This latter analysis was made to overcome possible limitations due to the fact that there was no real gap between the two groups of poor and good spellers. One might thus consider (this point was suggested by a reviewer) that the level of spelling proficiency should be treated as a continuous variable to be introduced as a co-variable in the analysis of variance. Such an analysis was made and the results are similar to the previous ones: spelling level was significant [$F(1, 33) = 42.99$; $p < .001$], handwriting condition was significant [$F(1, 33) = 5.62$; $p < .05$], lexical spelling complexity of the words was significant [$F(1, 33) = 11.16$; $p < .01$], word class was significant [$F(2, 66) = 7.92$; $p < .01$]. The interaction between spelling level and handwriting condition was significant [$F(1, 33) = 4.03$; $p = .05$] (see Figure 5) as was the interaction between spelling level and lexical spelling complexity of the words [$F(1, 33) = 8.57$; $p < .01$] (see Figure 6).

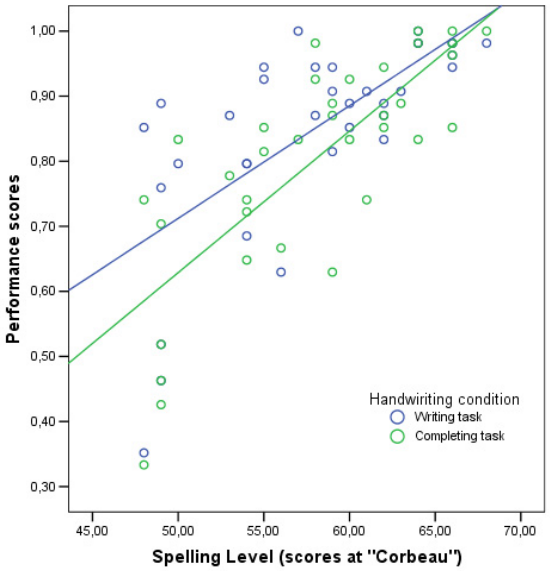

Figure 5. Proportions of correct agreements as a function of spelling level (continuous dimension) and handwriting condition

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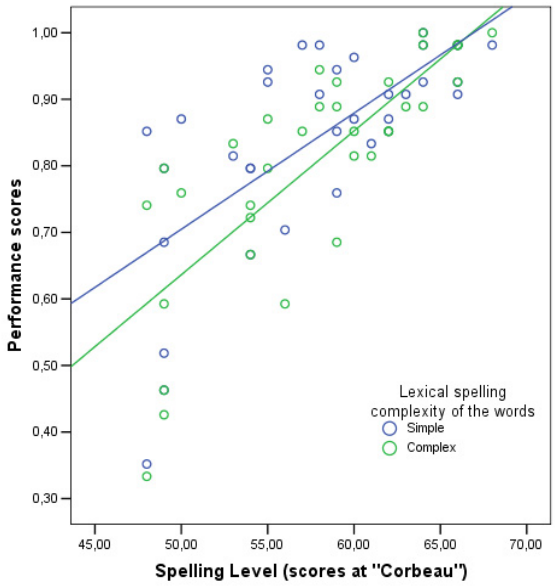

Figure 6. Proportions of correct agreements as a function of spelling level (continuous dimension) and lexical spelling complexity of the words

Figure 6 Proportions of correct agreements as a function of spelling level (continuous dimension) and lexical spelling complexity of the words.

In the second task of our study, the dependent variable was the percentage of verbs with correct agreements, whether singular or plural. Table 5 shows the percentages of correct agreements per spelling level as a function of the syntactic distance between subject and verb. On the whole, children correctly agreed most of the items (80%); they did not put the agreement mark in 17 % of items, and put the wrong mark in only 3 %. An analysis of variance with one intra-subject factor (the syntactic distance: short *vs.* long distance) and one inter-subject factor (spelling level: low- *vs.* high-level) shows that the *spelling level* had a main significant effect [$F(1, 33) = 7.91$; $p < .01$]. Low-level children correctly agreed less number of verbs (69.6%) than high-level children (88.3%). The *syntactic structure* had a main significant effect [$F(1, 33) = 6.27$; $p < .02$]; there were more correct agreements when the syntactic distance is short (82.0%) than when it is long (75.9%). Interaction between syntactic structure and spelling level was not significant [$F(1, 33) = 1.29$; $p = .26$].

Table 5. Mean performance scores of verbs correctly agreed per spelling level (standard deviations between brackets)

		Sentence structure	
Level	**N**	**Simple**	**Complex**
Low	15	74.1 (23.6)	65.2 (24.1)
High	20	90.0 (17.6)	86.7 (18.6)

4. Discussion

The aim of this study was to understand why children have some difficulty in mastering the agreement operation. Globally, the reported observations show that the additional processing costs involved in the management of the handwriting activity as well as of both the lexical spelling and structural complexity of the linguistic materials may prevent the agreement process from working properly.

No one doubts that the handwriting activity in itself is cognitively costly; even for 8 to 10-years-old children, it still requires much attention and much application (Bourdin & Fayol, 2000) that is likely to result in slowing writing speed (Zesiger, 1995). Our study further shows that the costs of the organizing control and of the writing behaviour affect the production of a correct agreement; reducing these writing costs increases the agreement performance. Yet, this is only true for low-level spelling children; high-level spelling children are no longer sensitive to the writing costs (and/or to the word retrieving costs), which is consistent with the hypothesis that their handwriting motor skills are more developed.

As regards the effect of the lexical spelling complexity of the words, low-level spelling children are better able to agree short, consistent words with a simple syllable structure than long, inconsistent words with a complex syllable structure. High-level spelling children's agreement performance appears to be no longer sensitive to the lexical spelling complexity of the words. It can be hypothesised that this is due to the fact that their orthographic lexical representations are of a better quality, and therefore require fewer resources to be retrieved in a sentential writing context.

Regarding the joint influence of these factors, the hypothesis was that children would make fewer words agree under the conditions in which the cognitive costs associated with lexical spelling processing and handwriting activity are greatest, that is, when they have to write complex words (compared with complete simple words). This hypothesized interaction is supported by our observations. First, it clearly appears that the cost of the lexical spelling complexity only affects the agreement operation in the writing condition. Second, it also appears that the cost of the handwriting activity only affects the agreement operation for lexically complex words. In short, writing lexically complex words and completing lexically simple words are respectively the most difficult and the easiest conditions. This observation might be viewed as consistent with

the idea that the cognitive costs involved in handwriting activity and orthographic processing are cumulative.

As regards the word class effect, in line with previous studies (Totereau *et al.*, 1997; Largy, 2001), children correctly agreed more nouns than verbs, and more verbs than adjectives. This last observation is in contrast with Fayol *et al.* (2006) who found that children from second to fifth grades agree the same proportions of verbs and adjectives. This discrepancy between the two studies can be explained by the context of the agreement that had to be produced. While Fayol *et al.* tested the agreement of nouns, adjectives and verbs all in the same sentence [e.g., *"Les filles blondes parlent";* The blond girls talk], we evaluated the three word classes in separate sentences [e.g., noun *"Les lapins couraient dans les champs"* (The rabbits ran in the fields), verb *"Les sportifs participent à la course de l'école"* (The sportsmen take part in the school race), adjective *"Les garcons raisonnables seront bien récompensés"* (The well-behaved boys will be well rewarded)]. It may be hypothesised that adjectives are more easily agreed after the use of a plural mark for the preceding noun in Fayol *et al.*'s study. In a second study, Fayol *et al.* (2006) replicated their results with one sentence by items (like us) but only in a completion task. However, children were instructed to complete only the agreement mark; this kind of instruction clearly makes the agreement apparent: children know that they have to put a plural mark. It is also worth noting that children in Fayol *et al.*'s study made up to ten times more confusion errors than our children (e.g., they use the noun marker instead of the verb mark simply because they have to put a mark).

As regards the effect of structural processing, we predicted that high-level spelling children would be more influenced by the type of sentence structure than the low-level spelling children. Since high-level spelling children are likely to have automated spelling operations (both lexical and grammatical), we predicted that, as observed by Fayol *et al.* (1999), they would make more agreement errors in complex sentences, because they would make proximity concord errors which are typical errors for adults [e.g., "*Les amis du pêcheur arrive*…." (The friends of the fisherman arrives…")]. Our results show that all children find it easier to make verbs agree in sentences with a short syntactic distance between the subject and the verb than in sentences with a long syntactic distance, as expected. But the effect of syntactic structure does not appear to vary as a function of the spelling level. It could be, however, that children with higher spelling level or children older than 12 years make fewer verbs agreements in long syntactic distance, as observed by Frisson and Sandra (2002) with 14 year-old participants.

On the whole, these results show that low-level spelling children are influenced by the cognitive cost of the handwriting and the lexical processes when they produce agreement whereas this is no longer the case for high-level spelling children. This may explain the observation that children are able to understand marks of agreement or correct them well before they are able to produce them correctly (Largy, 2001; Totereau *et al.,* 1997).

In a more descriptive way, considerable inter-individual variability was observed within the results. This variability undoubtedly reflects the abilities of each individual on a grammatical level, which is the knowledge of the rules and the ability to apply them. However, this variability might also be a reflection of the children's skills in handwriting and spelling. Further studies should evaluate children's handwriting skills in more detail, so as to understand better the relation between the development of fine motor skills and the acquisition of both lexical and grammatical spelling. It may be possible to measure the level of handwriting development with a standard test like BHK (Charles, Soppelsa, & Albaret, 2003) and to assess the correlation between children's performances in handwriting and in lexical and grammatical spelling. It would also be interesting to monitor the performance of children who have problems in learning to spell and who have poor handwriting ability (Connelly, Campbell, MacLean, & Barnes, 2006); it might be observed that the cognitive costs associated with handwriting and lexical retrieval processes have much influence on the agreement performance of these children.

Finally, the observations reported here have some educational implications. The influence of the cognitive cost associated with lexical spelling processing and handwriting ability on agreement processing leads us to believe that a graduation in difficulty levels for agreement school exercises should be proposed. It might be sufficient to first allow the children to perform activities involving completing the endings of words. Then, when this task has been successfully completed, they could perform agreement tasks involving writing simple words, followed by complex words, before tasks that require the writing of whole sentences.

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APPENDIX

Appendix A – Experimental items: word section

Type	Simple words	Complex words
	Liste A	
Nouns	les lapins	les grenouilles
	les rues	les gourmandises
	les poires	les personnages
	les jupes	les expositions
	les motos	les hélicoptères
	les dames	les portefeuilles
Verbs	les chevaux tirent	les chevaux escaladent
	les prix montent	les prix dégringolent
	les papas fument	les papas plaisantent
	les sportifs avalent	les sportifs participent
	les clowns imitent	les clowns émerveillent
	les habitants adorent	les habitants frissonnent
Adjectives	des paysages variés	des paysages gigantesques
	des hommes polis	des hommes responsables
	des yeux vifs	des yeux particuliers
	des garçons doués	des garçons raisonnables
	des sacs dorés	des sacs tranparents
	des arbres jaunes	des arbres remarquables
	Liste B	
Nouns	les robes	les citrouilles
	les coudes	les photographes
	les vélos	les prisonniers
	les amis	les marchandises
	les menus	les dictionnaires
	les dates	les bicyclettes
Verbs	les secrétaires tapent	les secrétaires travaillent
	les dames lavent	les dames surveillent
	les braconniers tuent	les braconniers recherchent
	les voisins louent	les voisins questionnent

	les parents dînent	les parents manifestent
	les militaires étalent	les militaires interpellent
Adjectives	des animaux marins	des animaux fantastiques
	des fauteuils durs	des fauteuils confortables
	des monstres poilus	des monstres surprenants
	des chants jolis	des chants traditionnels
	des livres rares	des livres exceptionnels
	des travaux utiles	des travaux obligatoires

Appendix B – Experimental items: sentence section

Types	Sentences
	Simple
Singular	Le pompier arrose les trois voitures en feu sur la route
	Ma tante prépare un gâteau au chocolat pour notre fête
	L'infirmier mesure la taille des enfants chaque année
Plural	Les acteurs tournent un nouveau film sur Napoléon
	Les touristes observent les animaux de notre région
	Les taxis transportent les ministres jusqu'à la maison
	Les garçons préfèrent aller voir le foot au stade ce soir
	Les élèves terminent leurs devoirs avant d'aller jouer
	Les nouveaux jeux amusent beaucoup mes compagnons
	Complex
Singular	La soeur de notre meilleure amie gagne souvent au tennis
	L'enfant de mon plus jeune frère tombe très souvent
	Le gagnant de la dernière saison félicite le joueur
Plural	Les filles de ce célèbre musicien chantent ce soir
	Les chiens de la grande maison réveillent tout le monde
	Les vendeuses de l'autre magasin rigolent souvent
	Les parents de la petite chanteuse arrivent demain matin
	Les ouvriers de notre nouveau patron discutent entre eux
	Les poules de notre vieux boulanger mangent beaucoup

Appendix C – Instructions given to the children

Writing task

« Je vais lire des phrases. Dans ces phrases, il y a des trous, il y a des mots qui manquent. Tu vas d'abord :

1. *écouter la phrase sans écrire puis*
2. *je vais redire la phrase et tu vas écrire les mots qui manquent.*

Si tu ne sais pas comment on écrit un mot, tu essayes quand même. Tu fais du mieux que tu peux et ce n'est pas grave si tu n'es pas sûr. »

"I will read sentences. In those sentences, there are missing words. You will first:

1. listen to the sentences without writing
2. I will reread sentences and you will write the missing words.

If you don't know how to write a word, just try it. Do the best you can."

Completing task

« Je vais lire des phrases. Dans ces phrases, tous les mots sont bien écrits sauf deux où il manque des lettres. Il manque 1, 2 ou 3 lettres. Tu dois compléter les deux mots en gras. Tu vas d'abord :

1. *écouter la phrase sans écrire puis*
2. *je vais redire la phrase et tu vas compléter les mots en gras. »*

"I will read sentences. In those sentences, all words are correct except two who have missing letters. One, two or three letters are missing. You must complete those words in bold. You will first:

1. listen to the sentences without writing
2. I will reread sentences and you will complete the words in bold."